Null Instanton Model on Hadron Mass Spectroscopy, Magnetic Moments of Baryons and Origin of Matter

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A null-instanton induced operator-type potential is applied to the baryon and meson mass spectra and the magnetic moments of baryons. A theory begins with a pure exchange operator under the presence of quarks and anti-quarks. The strength operator of the potential admits both signs, viz., totally zero, suggesting an existence of the sign inverted partner of a given hadronic state. A unit operator becomes a sum of spin 0 and 1 projection operators. An operator property of the multiplicative strength of the potential takes suitable eigenvalues depending upon the properties of operands which is made from a quark (quark-antiquark) pairs in hadrons. Fixing the induced parameters of the theory by an appropriate choice of a set of inputs, one is able to predict many sign inverse partners in conformity with observed baryon and meson mass spectra. In a study of baryon magnetic moments a pure photon term and the null-instanton affected term are treated explicitly so as to clarify the physical meaning of the effect. The theory admits one to speculate on the origin of matter.

$ 1. Introduction

Recently, Bukina[1] has compared the magnetic moment results of quark model in null-instanton approach,[2] with the extended broken SU_3 electromagnetic current[3] and semi-bosonized Nambu-Jona-Lasinio model.[4] She has pointed out an equivalence of three approaches in the sense that all of them are classified as members of unitary symmetric model.

A physical content of instanton has been discussed extensively by Zinn-Justin.[5] He has pointed out the instanton induced interaction has a strong spatial-distance dependence and diminishes quickly with the increase of it.

Let us assume that the instanton number cancel to zero for quark pair (and quark anti-quark pair) even if the individual instanton number associated with each quark is non-zero except for unpaired quark where it should be zero, because the meson and baryon should not carry non-zero instanton number.

Giving a special role on quark pair in terms of instanton number under the assumed flavor SU_3 symmetry, one gets a merit to explain the hadron mass spectra in terms of the null-instanton induced operator-type potential.

We formulate our theory starting from a set of quarks and anti-quarks with a quark exchange operator which is multiplied with an strength operator by admitting both signs, viz., totally null potential. A unit multiplicative operator of the potential splits into spin zero and one projection operators as a source of the mass splitting of octet (nonet pseudoscalar) and decuplet (nonet vector) baryon (meson) masses, where the multiplicative strength operator get its eigenvalues corresponding to the quark (quark-antiquark) pairs in baryons (mesons) owing to the symmetry breaking of flavor SU_3 symmetry. In this study the Pauli exclusion principle for a fermion system plays an important role to fix the sign of the expectation value of the given potential. An original nullity of the operator without matter predicts the existence of the potential-strength-sign-inverted partner for any hadronic state. For such a partner we shall put subscript inv from now on to the original accustomed state in order to discriminate it from the latter.

In what follows, the many baryon and meson inverse partner's mass spectra[5,6] are predicted numerically once the eigenvalues of the strength operator are fixed suitably.

A fitting procedure is as follows. We start from an estimate of strange quark mass and one of the relevant potential strength from the observed Ω and ϕ meson mass which admit us to predict Ω_{inv} (2252± 9) in P_{03} at 2249 MeV, although its spin and parity have not yet been determined. The non-strange particle associated parameters are determined from N and Δ by combining either N_{inv}(2100) or Δ_{inv}(1920) as their respective partners. The both choices give almost the same prediction. The strange-hadron associated strengths are fixed by making use of the well-known Λ, Σ and Ξ masses and those fixed above.

The magnetic moments of decuplet and octet baryons have also been estimated by a pure quark term and symmetry breaking effect separately, which teaches us the physical meaning of the associated parameters in the previous study. We have included s-s exchange effect in this study so that only one (two in principle) sum rule(s) can be derived.

It is attractive to consider a Heisenberg's monism[7] of fermions including leptons as the source of matter formation. In this connection it is interesting to ask why SU_3 octet (8'), in which two quarks couple first antisymmtrically and the third one in a mixed symmetry in Young tableaux, is not realized in nature and a singlet (1) baryon as well. The nature has chosen only octet (8) in which first two quarks couple symmetrically and the third one in the mixed symmetry. It is interesting to point out that SU_2 quartet and doublet baryon wave functions[8] has the same structure as those of Δ and N in SU_3, respectively. The same applies to SU_2 doublet and singlet pion wave functions. When they become SU_3 octet members they keep their internal structure as an isospin triplet wave functions.

Notice that the degree of freedoms associated with decuplet and octet baryon 18 correspond to 18 ones of pseudoscalar and vector nonet mesons. This is consistent with the non-appearance of the SU_3 singlet baryon.

$ 2 is devoted to the derivation of mass formulae and their application. The newly derived magnetic moment formulae and the associated sum rules are discussed in $ 3. In $ 4 we summarize our work and a future prospect of the theory. We shall postpone our speculation on matter formation up to Appendix I. The SU_3 baryon 8' and 1 mass formulae are discussed in Appendix II for completeness.

$ 2. Hadron Mass Formula

We shall confine ourselves mainly to the mass formulae for light particles belonging to the flavor SU_3 and touch shortly on the wave functions for c, b and t associated baryons by assigning them as the 6, 3 and 1 members of SU_3 subgroup of the bigger flavor groups SU_4, SU_5 and SU_6, respectively. One may find, e.g., baryon and meson towers in SU_4 in an earlier publication of the Particle Data Group.[9]

The construction of the effective potential begins with the i-th and j-th quark exchange operator P_{ij} where i and j indicate all quantum numbers associated with the given quarks. We assume the same exchange operator applies including anti-quarks so our theory automatically includes them notwithstanding explicit statement. The unit multiplicative operator will be splitted into spin 0 and 1 projection operators multiplied with a strength operator c.

An explicit form of the potential is given by:

$$c\left(\frac{3+\sigma_i.\sigma_j}{4} + \frac{1-\sigma_i.\sigma_j}{4} \right) P_{ij} , \qquad (2.1)$$

The eigenvalues of c are determined by the properties of the quark pairs as operands under the operation of c in a given state. There are only two kinds of spins of quark pairs in baryons and mesons, viz., anti-parallel and parallel ones. Let us introduce a short notation q = u, d. There appear three sets of eigenvalues depending upon quark-pair spin states a0, a1, b0, b1 and c0, c1 under q-q ($\bar{q}$), q-s($\bar{s}$) and s-s($\bar{s}$) exchange, respectively. Here 0 and 1 represent anti-parallel and parallel spin, respectively. We expect various additional indices in future study so these notations are suitable for our purpose.

It is easy to generalize Eq.(2.1) to the relativistically invariant propagator in quantum field theory, since the scalar product of 4-dimensional gamma matrices contains the two scalar product of 2-2 Pauli spin matrices in its space part.

One should remind indices i and j in Eq.(2.1) should be summed over appropriately: (i) quark spin and color indices etc. are exchanged simultaneously if it is admitted, (ii) each component of wave function conserves number of q-q(q') pairs, viz., each admits only the exchange of the same color (color and its conjugate one between q-$\bar{q}'$ in case of mesons), where there does not occur the overlapping of the components of the wave function, (iii) the relative weight of each component of it determines the contributing rate of different q-q' pairs, (iv) once the matrix elements of the interest is determined for the specific hadron, it is generalized easily so as to accommodate with a radial or an orbital excitations, since the corresponding parameters for these excitations behave as bosonic ones, (v) in general a single, double and triple bond excitations are admitted for a baryon and one for a meson if it consists of a single q-$\bar{q}'$ pair, and (vi) notice finally that in order to complete three successive q-q pair exchanges in the baryon we should spend three more times than to complete one bond on average, which is reflected to the meson mass formula, or one can consider that here the summation indices in potential operator run over three different (mutually conjugate pairs of) colors.

As far as we examined, the introduction of one bond excitation in both orbital and radial excitation is sufficient to explain the presently available baryon mass spectra under the presence of the sign inverse states. The two and three bond excitations correspond to the highly excited states not reached yet so far.

Let us present first the mass formulae of baryons by neglecting two kinds of excitations discussed above. In the following the particle symbol is used as its mass and quark symbols as their effective masses. By putting u=d we find baryon mass formula:

$$N = 3\,u - 2\,a0 - a1\,, \qquad (2.2a)$$

$$\Lambda = 2\,u + s - a0 - b0 - b1\,, \qquad (2.2b)$$

$$\Sigma = 2\,u + s - \frac{1}{3}(a0 + 2\,a1 + 5\,b0 + b1)\,, \qquad (2.2c)$$

$$\Xi = u + 2\,s - \frac{1}{3}(5\,b0 + b1 + c0 + 2\,c1), \qquad (2.2d)$$

for the octet baryons.

$$\Delta = 3\,u - 3\,a1, \qquad (2.3a)$$

$$\Sigma^* = 2\,u + s - a1 - 2\,b1, \qquad (2.3b)$$

$$\Xi^* = u + 2\,s - 2\,b1 - c1, \qquad (2.3c)$$

$$\Omega = 3\,s - 3\,c1, \qquad (2.3d)$$

for the decuplet baryons.

The meson mass formulae become:

$$\pi = 2\,u - 3\,a0, \qquad (2.4a)$$

$$K = u + s - 3\,b0, \qquad (2.4b)$$

$$\eta = \frac{2}{3}(u + 2\,s) - a0 - 2\,c0, \qquad (2.4c)$$

$$\eta' = \frac{1}{3}(4\,u + 2\,s) - 2a0 - c0, \qquad (2.4d)$$

for the pseudoscalar nonet. If there is an η_s as a substitute of η', say, as the bound spin zero $s\bar{s}$ state, its mass formula becomes

$$\eta_s = 2\,s - 3\,c0. \qquad (2.4d)'$$

The vector-meson mass formulae are given by:

$$\rho = 2\,u - 3\,a1, \qquad (2.5a)$$

$$K^* = u + s - 3\,b1, \qquad (2.5b)$$

$$\omega = \frac{2}{3}(u + 2\,s) - a1 - 2\,c1, \qquad (2.5c)$$

$$\phi = 2\,s - 3\,c1, \qquad (2.5d)$$

for the nonet. In case of ϕ we assumed that it is a pure $s\bar{s}$ spin 1 bound state so as to accommodate with the well known Okubo-Zweig-Iizuka (OZI) rule. We have omitted the SU_3 octet and singlet mixing angle for mesons in these equations.

Substituting the observed masses in Eqs.(2.3d) and (2.5d) and solving the coupled equations with respect to s and c1 one finds

$$s = 653.037 \quad \text{and} \quad c1 = 95.5537, \qquad (2.6)$$

in units of MeV. Making use of these numbers we predict Ω_{inv} (2252) at 2249 as stated already in introduction. The experimental confirmation of its spin and parity is highly awaited. We shall use MeV in mass units and omit it for simplicity hereafter. We have tried two choices of fit in order to fix u, a0 and a1 parameters: (i) N, Δ and Δ_{inv}(1920), or (ii) N, Δ and

$N_{inv}(2100)$ as inputs. where $\Delta_{inv}(1920)$ and N_{inv} (2100) are chosen as the sign inverted partner of Δ and N, respectively. Combining Eqs.(2.2a) and (2.3a) and the sign inverted one in each set one finds nearly the same numerical solutions:

$$u= 525.333, \quad a0 = 261.207, \quad a1 = 114.667 \qquad (2.7a)$$

and

$$u= 506.486, \quad a0 = 246.360, \quad a1 = 95.8198 \qquad (2.7b)$$

for inputs (i) and (ii), respectively. The remaining parameters b0, b1 and c0 are determined from the observed masses of Λ, Σ and Ξ and Eqs. (2.2b)-(2.2d), (2.6), (2,7a) or (2.7b): one finds

$$b0 = 178.573, \quad b1 = 148.240, \quad c0 = 307.674 \qquad (2.8a)$$

and

$$b0 = 169.149, \quad b1 = 138.817, \quad c0= 307.677 \qquad (2.8b)$$

corresponding to the fixed numbers in Eq. (2.6), Eqs.(2.7a) and Eq.(2.6), Eqs.(2.7b), respectively.

As we have stated already either sets of numbers in Eqs.(2.6), (2.7a) and (2.8a) or in Eqs.(2.6), (2.7b) and (2.8b) give almost the same prediction, we shall present the comparison of the predicted masses with their corresponding ones based on the former sets of numbers.

In the following the experimental mass may be written first in association with a particle symbol and puts predicted value in just after each symbol. The quantum numbers of many states have not yet been determined. When they are known we shall put them in between the symbol and the predicted mass. Some of baryon masses become: $\Sigma^*(1384.57)$ P_{13} 1292.54; $\Sigma_{inv}^*(2080)$ P_{13} 2114.87; $\Xi^*(1533.4)$ 1439.36; $\Xi_{inv}^*(2250)$ 2223.46.

The meson masses become:
$\pi(138.039)$ 0^- 267.045; π_{inv} (1800) 0^{-+} 1834.29; K (497.675) 0^- 642.651; $K_{inv}(1830)$ 0^- 1714.09; $\rho(770)$ 1^- 706.665; $\rho_{inv}(1405)$ 1^{-+} 1394.67; $\omega(781.94)$ 1^{--} 915.164; $\omega_{inv}(1420)$ 1^{--} 1526.71; K*(892) 1^- 733.623; $K_{inv}^*(1410)$ 1^- 1623.12; $\eta(547.30)$ 0^{-+} 344.383; $\eta_{inv}(2225)$ 0^{-+} 2097.49; η' (957.78) 0^{-+} 305.714; η_{inv}'(---) 1965.89.

One interesting remark in connection with these is η_s and its partner's mass. We find numerically $\eta_s(957.78)$ 0^{-+}383.052; $\eta_{sinv}(2225)$ 0^{-+} 2229.10. Therefore one cannot exclude completely this possibility as far as the good numerical fit on η_{sinv} concerns.

From these analyses one may find that some of the light ps-mesons may have slightly extended structure than the baryons as suggested from the use of null-instanton induced potential in the theory.

Throughout these studies one may find that not only baryons have their sign inverted partners but also the mesons do.

We have omitted from above lists $N_{inv}(2100)$ and $\Delta_{inv}(1920)$ in fits (i) and (ii), respectively. They are given by 2213.08 and 1806.92 correspondingly. These numbers tell us a rough idea on an accuracy of our numerical fit. We hope that the theory gives a more and more accurate prediction numerically by the improved inputs.

The radial- and the orbital-excitation mass spectra may easily be obtained by starting from the equations derived above. As mentioned already there are a single, double and triple bond radial (orbital) excitations for baryons in general. The required modification can be done by taking the bosonic nature of these excitations into account. Based on the observed baryon mass spectra let us exemplify it by N spectra, by confining solely to a single bond excitation. One finds

$$N(r) = 3\,u + r - 2\,a0 - a1, \qquad (2.9)$$

where r corresponds to a parameter representing the radial or the orbital excitation. The r will have spatial distance or orbital state dependence and a0 and a1 may also be reduced somewhat as will be expected from the fact that they represent the null-instanton induced potential strength. We shall postpone a detailed numerical application of both excitations to available data in future and discuss qualitatively a prospect of such a study. A close examination on so far untouched states of Δ may give the following numbers by admitting the existence of sign inverted partner of each state. An introduction of independent two radial excitations and 9 orbital excitations will be sufficient to explain the available data. The corresponding numbers for N and Λ become 2 and 7 and 2 and 5 (or 6), respectively. In these examples the first single-radial excitation appears as the first excited states of N and Δ, and as the third one for Λ. In the tabulation of the Σ and Ξ mass spectra their octet and decuplet states are mixed up unseparably. The former spectra may possibly be clarified in the course of persuit of our program and the latter requires a more data. Finally the mass spectroscopy of Ω is of interest since it is a pure SU_3 decuplet member and an almost pure three s quark bound system.

The additional baryon multiplets in flavor SU_4, SU_5 and SU_6 group can always be reduced to a few to several SU_3 (anti) sextets, (anti) triplets and singlets.[10] The singlet wave function is easily obtained. The remaining sextet and triplet wave functions can be constructed by an appropriate (symmetric or anti-symmetric) attachment of a new flavor to the SU_3 sextet and triplet wave functions, where the choice in the last bracket depends upon the structure of partner wave function.[8)] The SU_3 decomposition of meson wave functions form also the similar multiplets. The mass formula based on the null-instanton model for those new states can be derived easily. We shall return this problem in future.

Finally we should like to make a comment on glueball. Usually the quantum numbers of a gluon is assigned to be I=0, $J^P = 1^-$, color octet.[5)] In this assignment the number of gluons as the composites of the glueball becomes indefinite, while if it carries the negative charge conjugation parity like a photon and color triplet the maximum allowed gluon number becomes 6 as the composites of glueball, owing to the color singlet requirement of the observable state. In our model the gluon and hence the glueball can interact quark by the null-instanton induced quark exchange potential with a slightly modified form diagrammatically but the admixing of glueball and the neutral meson carrying the same quantum number in a usual sense may not occur. The same applies to that between mesons composed purely of quark composites, since no admixing of the components of wave function is allowed under the scalar potential assumed as far as the internal quark structure of the two states is different as can be proved easily.

$ 3. Magnetic Moment of Baryons

It is instructive to start from the study of magnetic moment (abbreviated as m.m. for singular and plural hereafter) of the baryon decuplet. The pure m.m. term, which arises from a single quark interacting with a photon summed over all composites, which will get an additional modification, when each of them interacts with remaining quark by the null-instanton induced potential in succession. Again such a strong interaction effect should be summed over cyclically. The final results always expressed as a sum of a pure SU_6 result with an additional correction if we treat the broken effect in units of the quark m.m.

The effective quark m.m. are defined in units of nuclear magneton by

$$\mu_u = \frac{2}{3}\mu, \qquad \mu_d = -\frac{1}{3}\mu, \quad \text{and} \quad \mu_s = -\frac{1}{3}\mu' \tag{3.1}$$

for u, d and s quark, respectively. We shall derive the m.m. of each baryon belonging to the SU_3 decuplet and octet representations in this order and then discuss their mutual relations. Let us start from the m.m. of Δ baryons:

$$\mu_{\Delta^{++}} = 2(1-2\,a1)\,\mu, \quad \mu_{\Delta^+} = (1-2\,a1)\,\mu, \quad \mu_{\Delta^0} = 0, \quad \mu_{\Delta^-} = -(1-2\,a1)\mu, \tag{3.2a}$$

where the use is made of the same notation for breakon effect as those in the previous section. They may be proportional to each other but the absolute magnitudes as well as units are completely different. Here, they are dimensionless parameters. One sees that only parallel quark-pair spin-effect appears in these expressions. We follow the same convention throughout this section. The m.m. of Σ^* are given by:

$$\mu_{\Sigma^{*+}} = \frac{4}{3}(1 - a1 - b1)\mu - \frac{1}{3}(1-2\,b1)\mu',$$

$$\mu_{\Sigma^{*0}} = \frac{1}{3}(1 - a1 - b1)\mu - \frac{1}{3}(1 - 2\,b1)\mu', \tag{3.2b}$$

$$\mu_{\Sigma^{*-}} = -\frac{2}{3}(1 - a1 - b1)\mu - \frac{1}{3}(1 - 2\ b1)\mu'.$$

Those for Ξ^* become:

$$\mu_{\Xi^{*0}} = \frac{2}{3}(1 - 2\ b1)\mu - 2/3(1 - b1 - c1)\mu',$$

$$\mu_{\Xi^{*-}} = -\frac{1}{3}(1 - 2\ b1)\mu - \frac{2}{3}(1 - b1 - c1)\mu'. \qquad (3.2c)$$

and finally the m.m. of Ω^- becomes:

$$\mu_{\Omega^-} = -(1 - 2\ c1)\mu' \qquad (3.2d)$$

Starting the estimate of the m.m. for octet baryons from those of p and n, one finds:

$$\mu_p = (1 - a0 - a1)\mu, \qquad \mu_n = -\frac{2}{3}(1 - \frac{3}{2}\ a0 - \frac{1}{2}\ a1)\mu \qquad (3.3a)$$

Those for Σ become:

$$\mu_{\Sigma^+} = \frac{1}{9}[(8 - 8\ a1 + 3\ b0 - 2\ b1)\mu + (1 - 3\ b0 + b1)\mu'],$$

$$\mu_{\Sigma^0} = \frac{1}{18}[(4 - 4\ a1 - 3b0 - b1)\mu + 2(1 - 3\ b0 + b1)\mu'], \qquad (3.3b)$$

$$\mu_{\Sigma^-} = \frac{1}{9}[(-4 + 4\ a1 + 3\ b0 + b1)\mu + (1 - 3\ b0 + b1)\mu'].$$

That of Λ is given by:

$$\mu_\Lambda = -\frac{1}{3}[(1 - b0 - b1)\mu' - \frac{1}{2}(b0 - b1)\mu]. \qquad (3.3c)$$

There exists a magnetic-dipole radiative transition from Σ^0 to Λ. The associated transient m.m. is measured experimentally with its sign left undetermined. The corresponding theoretical m.m. becomes:

$$\mu_{\Sigma^0\Lambda} = -\frac{1}{2\sqrt{3}}[2(1 - a0) - b0 - b1]. \qquad (3.3d)$$

Finally those for Ξ hyperons are estimated to be:

$$\mu_{\Xi^0} = -\frac{1}{9}[2(1 - 3\ b0 + b1)\mu + (4 - 3\ b0 - b1 - 4c1)\mu'],$$

$$\mu_{\Xi^-} = \frac{1}{9}[(1 - 3\ b0 + b1)\mu - (4 - 3\ b0 - b1 - 4\ c1)\mu']. \qquad (3.3e)$$

We shall start with the m.m. sum rules for decuplet baryons. One may find easily from Eqs.(3.2a) that

$$\mu_{\Delta^+} + \mu_{\Delta^-} = 0, \qquad (3.4)$$

and

$$\mu_{\Delta^{++}} = 2\mu_{\Delta^+}. \qquad (3.5)$$

One gets from Eqs. (3.2b) the well-known sum rule of Marshak, Okubo and Sudarshan[11] which is derived under the charge independence hypothesis, viz.,

$$\mu_{\Sigma^+} + \mu_{\Sigma^-} = 2\mu_{\Sigma^0}. \qquad (3.6)$$

This gives a counter check of the validity of our approach. One more simple sum rule is found by combining Eqs.(3.2c) and (3.2d), viz.,

$$(1 + \frac{\mu'}{\mu})\mu_{\Xi^{*0}} + (2 - \frac{\mu'}{\mu})\mu_{\Xi^{*-}} = \mu_{\Omega^-}. \qquad (3.7)$$

Before discussing m.m. sum rules on octet baryons it is appropriate to eliminate c1 from Eqs.(3.2d) and (3.3e). One finds:

$$\mu_{\Xi^0} + 2\mu_{\Xi^-} - \frac{2}{3}\mu_{\Omega^-} = -\frac{1}{3}(2 - 3\ b0 - b1)\mu'. \qquad (3.8)$$

There are 8 data on octet baryons including the transient moment and the combined three data appeared on the left hand side in Eq.(3.8), by noticing that this relation is the m.m. relation between 3 data so it should be counted as 2 data. For the time being the experimental accuracy of the combined data is better than that of the transient one. If we choose the former as input there remains 7 inputs and 6 parameters so in principle we confine ourselves to a single sum rule. We find two sum rules: one is linear and the other the quadratic one with respect to the m.m. The former is an unexpected one at the beginning and the latter is a natural one, since the coupled equations themselves are quadratic with respect to the parameters. The results are:

$$2\mu_{\Sigma^-} + \mu_{\Sigma^+} = \mu_{\Xi^-} - \mu_{\Xi^0} \, , \tag{3.9}$$

$$(-2.32 = -1.86),$$

and

$$12\mu_n(-12\mu_{\Xi^-} + 3\mu_{\Xi^0} + 2\mu_{\Omega^-}) = 12\mu_p(12\mu_{\Xi^-} - 3\mu_{\Xi^0} - 2\mu_{\Omega^-}) +$$
$$27\mu_{\Xi^-}(-12\mu_{\Xi^-} - 11\mu_{\Xi^0} + 8\mu_\Lambda - 4\mu_{\Sigma^+}) + 9\mu_{\Xi^0}(-3\mu_{\Xi^0} + 12\mu_\Lambda + 3\mu_{\Sigma^+}) +$$
$$2\mu_{\Omega^-}(105\mu_{\Xi^-} + 39\mu_{\Xi^0} - 36\mu_\Lambda - 16\mu_{\Omega^-} + 9\mu_{\Sigma^+}) \, , \tag{3.10}$$

$$(0.422 = 1.001).$$

Here we have shown the estimated numerical values in units of n.m. (nuclear magneton) and $(\text{n.m.})^2$ corresponding to the left- and right-hand-side of each equality by making use of presently available data inside a bracket under each relation. We use the same units hereafter and omit them unless stated otherwise. The numerical results are not too bad, especially in the latter in spite of the appearance of large multiplicative numerical factors in each term. We hope that a future experimental work improves the result.

It is amusing to examine the physical meaning of the parameters introduced in a previous study[2)] in terms of the present work, especially to get some numerical information on p, n and strange baryon relevant parameters in this study even approximately.

Comparing the m.m. of p and n in this work and those in a previous work[2)] one finds that

$$\alpha = -(3\,\text{a0} + \frac{1}{3}\,\text{a1})\mu \, , \qquad z = -\frac{3}{2}(3\,\text{a0} + \text{a1}). \tag{3.11}$$

where α and z are symmetry breaking parameters in units of 1 n.m. and a correction to pure u-quark m.m. introduced by intuition, respectively, although we neglected the s-s exchange effect completely in the previous study.

If we assume an approximate validity of an expression

$$\frac{a0(s.i.)}{a0(m.m.)} = \frac{a1(s.i.)}{a1(m.m.)} \tag{3.12}$$

and a similar equality between b0 and b1, we can estimate the non-strange and strange particle associated m.m. parameters numerically, where s.i. means a strong interaction. The result is presented in Table I.

Table I. Numerical values of m.m. relevant parameters

	input			input	
	(i)	(ii)		(i)	(ii)
μ (n.m.)	2.399	2.439	μ' (n.m.)	0.350	0.356
a0	-0.114	-0.104	b0	-0.0845	-0.0749
a1	-0.0500	-0.0411	b1	-0.0702	-0.0614

The (i) and (ii) in the second line in Table I and the numbers in the same column are based on inputs (i) N, Δ and Δ_{inv}(1920) and (ii) N, Δ and N_{inv}(2100) family in association with strange baryons, respectively. More precisely the first and the fourth column represent symbols of the non-strange and strange quark relevant parameters for the m.m., respectively. The second, third, fifth and sixth column are the corresponding numerical values. From these numbers one may get a rough idea on the variations of the parameter values in the strong and electromagnetic interactions for the bound quarks.

$ 4. Conclusion and Discussion

In this paper we have studied mass spectra of hadrons and the magnetic moments of baryons by taking into account the intrahadron quark-exchange force in the null-instanton model. The interaction starts from a totally null counter exchange-potential under the presence of quark-quark (quark-antiquark) pairs. The operator property of the strength and spin projection operators constructed from a unit operator in the potential admit us to project out automatically the desired symmetry breaking effect and internal spin structure of the system as the matrix elements. The sign inverted counter potential predicts the existence of the corresponding partner of each hadronic state and is confirmed successfully. First of all the effective s quark mass and one of the s-s exchange potential parameter have determined from Ω baryon and ϕ meson mass and lead to a prediction of $\Omega_{inv}(2250)$ as the counter particle of the Ω, provided that its spin and parity coincide with those of the latter. Assigning $N_{inv}(2100)$ and $\Delta_{inv}(1920)$ as the partners of N and Δ, respectively, and making use of the masses of three strange baryons, all the eigenvalues of the strength of the potentials are determined numerically. These numbers admit us to identify many sign inverted partners of the well-known hadrons. Once the mass formula for the s-state quark bound state is found, its extension to a radial and an orbital excitation is straightforward by taking the bosonic nature of the corresponding parameters. The method can be extended to heavy quark states by taking their transformation property in sub SU_3 into account, although we left untouched on many interesting problems in this starting work.

A separate estimate of pure bound quark term and symmetry breaking effect by making use of the same potential have been applied to the estimate of the magnetic moments of baryons. The operator property of the strength of the potential admits us to project out the proper relevant eigenvalues of the symmtry breaking effect to the magnetic moment of the system. The relation between the present and the previous result based on the

same idea is shown explicitly. The new sum rules has been derived and shown their numerical check together.

We are concerned mainly on s-wave q-q interactions in this paper. Making use of the same technique one can determine various partial wave associated parameters. A study of a p-wave decay of decuplet baryon to baryon octet and ps-mesons as well as that of vector mesons to a pair of ps-mesons provide us to find an additional information on p-wave q-q interaction parameters. Then the null-instanton model may be applied, such as, to the negative meson and antinucleon absorption by nucleon (nucleus) and also to the estimate of the symmetry breaking effect in various electroweak processes.

The method can be extended to the nuclei straightforwardly by making use of the same potential used in this paper, where the internucleon q-q exchange will replace the intrahadron one. A nuclear physicist will accept this idea by referring to the presence of the well-known Okubo-Zweig-Iizuka (OZI) rule. A number of exchanged quark pairs increases with the increase of mass number A which becomes totally $9\,{}_AC_2$ q-q bonds in general between the strongly interacting full nucleons of in the nucleus. Here9 is number of quark pairs relevant to the exchange interaction between two nucleons ${}_AC_2$ the binomial coefficient.

In order to take into account the symmetry-breaking effect to the magnetic moments of nucleus the number of quarks contributing to this q-q exchange should be treated in two distinct ways: (i) the number of quarks in the nucleon which contribute to the Schmidt value[12),13)] is reduced to two for a pure photon term, while (ii) it is reduced to one for the symmetry-breaking term by an affection of intraquark exchange effect, since the two quarks and a single quark are free from the electromagnetic interaction and symmetry-breaking in (i) and (ii), respectively. They should be joined to the game of internucleon q-q exchange between q in a host nucleon and ones belonging to the nearby(in general all) nucleon(s) in a given nucleus under the careful treatment stated above, where the exchange occurs solely between the same colored (charged) quarks as emphasized repeatedly.

One can imagine the null-instanton effect without making a detailed calculation including the excited states of nucleus, where sign inversion doubles the same nuclear states. This is a new merit in nuclear spectroscopy. We are studying the light nuclei as typical examples by taking into account their size variation so as to be consistent with the property of null-instanton potential. The full nucleon interaction under the assumed potential explains simultaneously the binding[14] as well as excitation energies.[15] For the time being this study is confined mainly to s-shell nuclei which contains p-wave excitation and the result will soon be submitted for publication.[16]

It is an amusing program that if the null-instanton model without having no more theoretical input succeeds to explain all the properties of a nucleus, one can then provide the unified method to cook particle as well as nuclear physics. We believe it is a possible one to challenge. The shell structure of the nucleus admit us to specify automatically the radial and orbital excitation quantum numbers of the given system. We think that it is necessary to supply such a theoretical information in conformity with the available experimental data in tabular form for each nucleus as an almost routine work in future, since nuclei (nucleus) not only provide(s) probes (a probe) to clarify the properties of fundamental interaction on the one hand but also give(s) the check of fundamental idea on the other. As far as we have examined without having detailed calculation, the proposed program can be accommodated with all the existing information on nuclei, such as, an origin of paring energy, even an qualitative understanding of nuclear deformation. As an another typical example, such as, an introduction of a hard core in an approach in current nuclear potential theory may automatically be taken into account so as to keep the color singlet nature of nucleon in a nucleus under the null-instanton induced q-q exchange. In general the wave function of the nucleus becomes a Slater determinant made from quark-composite SU_2 nucleon wave-functions accomodated with sub-shell ones. The prediction of unobserved virtual states for fixed A will also supply an additional information on the production of the stable matter formation in our universe. We shall discuss in Appendix I the matter formation confining solely to hadronic one.

Appendix I. Origin of Hadrons

A null-instanton model in this paper has started with a set of quarks and antiquarks and the interaction potential is introduced afterwards. In this sense the model has the chance to concern the matter formation in the earliest universe.

In a point-like universe a quantum fluctuation can produce a heavy particle together with its antipartcle. In order to give the quark as well as lepton masses as the eigenvalues of the mass projection operator, it is suitable to consider a Heisenberg's idea of monism of fermions. Let us call such a parent fermion h and specify its mass by m. All the known fundamental fermions should become daughters of it. The masses of the quark and lepton masses will be introduced by a mass projection operator P_q by

$$q = P_q \, m,$$

where q represents all the quark and lepton masses.

If there exists a sign inverted partner of h named h_{inv} which has a negative mass - m by looking from a vacuum of the original point universe. This becomes positive m from energy -m down universe which corresponds to the vacuum of our own present universe. The action of the uncertainty principle at an original point universe will admit the simultaneous production of h, h_{inv} and their antiparticles. Making our discussion as simple as possible let us assume m is order of the electroweak and strong interaction unification scale. The vacuum of our universe is a multiple of m below the original point universe comparable to the total mass of our own universe. How about the other known fermion sign inverted partner masses become ?. There are increasing experimental evidences that the neutrino may have tiny mass: first from the supernova explosion[17] and from many experimental evidences on neutrino oscillations.[18] The lower limit of the neutrino mass is given to be 80 eV from the dark matter physics.[19] The finite mass of the neutrino may admit the presence of its sign inverted partner. Suppose that the inversion point in the original point-like universe is positioned at m above the present universe in the fundamental level. The mass of the ν_{inv} becomes close to that of h and that of t_{inv}, e.g., the lightest among all the quarks. In this scenario e_{inv} is the heaviest one among the charged leptons. All sign inverse partners interact strongly and fuse and do strong decays at high energy of order m and finally reach their partners known as the fundamental constituent of hadrons and quickly decay into the stable nuclear constituents and leptons following the counter decay scheme as we know at present day physics in our universe.

We have confined our discussion by assuming that there is no more quarks and leptons in addition to the presently observed three families. If t' and b' exist, the quark mass spectra suggests b'/t mass ratio may be the same order as that expected from nearly equal b/c and d/u ratios.

Our speculation on hadron production in the earliest universe does not require any change under such a situation. In this short note we wish to explain the energy (mass) production of our universe from the vacuum in the original universe where Heisenberg's monism of fermions plays the fundamental role.

Appendix II. SU_3 8' and 1 Baryon Masses

We wish to spend some space to baryon mass formulae belonging to SU_3 8' and 1 representations and check their physical contents numerically. Let us express their masses by putting prime on 8' baryon symbols. We find

$$N' = 3\,u - 2\,a0 - b0, \quad \Sigma' = 2\,u + s - a0 - b0 - b1,$$

$$\Lambda' = 2\,u + s - \frac{1}{3}(a0 + 2\,a1 + 5\,b0 + b1),$$

$$\Xi' = u + 2\,s - b0 - b1 - c1. \tag{A.1}$$

Note that mass formulae of the known octet N and 8' N take the same expressions in spite of the different form of SU_3 wave functions, while the Λ and Σ mass formula in octet are interchanged in 8' representation and that of Ξ' takes completely different expression.

The unitary singlet baryon is usually indicated by Λ_0 and its mass becomes

$$\Lambda_0 = 2\,u + s - \frac{1}{3}(2\,a0 + a1 + 4\,b0 + 2\,b1). \tag{A.2}$$

Numerical study of these mass formulae proceed as follows. Since the baryon decuplet mass fomula and N ones are common in 8 and 8' spin 1/2 baryons. We use the common parameters s, c1,

u, a0 and a1 as those found in \$. 2 for a set (i) N, Δ, Δ_{inv}(1920) and (ii) N, Δ, N_{inv}(2100) with common Ω and ϕ inputs, respectively. Therefore there appears only the difference for the strange baryon section as far as the 8 and 8' baryon masses concern. We find

$$b0 = 265.601, \quad b1 = -16.2592, \quad c0 = 263.955 \tag{A.3}$$

and

$$b0 = 246.623, \quad b1 = -16.1255, \quad c0 = 263.955 \tag{A.4}$$

for (a) combined set (i) with strange baryon mass formulae in 8' members Eqs.(A.1) and (b) similarly for set (ii). Joining these numbers with known 5 parameters we find

$$\Lambda'_{inv} = 2291.72\ (2216.33), \quad \Sigma'_{inv} = 2214.25\ (2214.25),$$

$$\Xi'_{inv} = 2344.70\ (2307.01) \tag{A.5}$$

for set (a) (set (b)). Experimentally no candidate exist with masses close to these values. The similar study for Λ'_0 gives

$$\Lambda'_0 = 1154.42\ (1300.97), \quad \Lambda'_{0inv} = 2252.99\ (2324.15) \tag{A.6}$$

for set (a) (set(b)). Again there does not seem to exist the corresponding unitary singlet baryon as far as the numerical test concerns. The main reason that the unitary octet baryons are realized in nature is due to the similarity of Young tableaux between decuplet and octet baryons up to two quark states.

Finally we check the unitary-singlet baryon masses by making use of the parameters in \$. 2. We find

$$\Lambda_0 = 1154.42\ (1183.08), \quad \Lambda_{0inv} = 2252.99\ (1825.79). \tag{A..7}$$

for the set (i) (set (ii)) in \$. 2. There is one candidate Λ_{0inv}(1810) corresponding to the last number in bracket in Eqs. (A.7) as P_{01} state but no Λ'_0 =1183.08 is found unless the well known Λ is represented as the simultaneous eigenstate of SU_3 octet and singlet wave functions. We consider that this example is an acccidental numerical coincidence. All the observed Λ states can be interpreted as members of the unitary octet.

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